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SEX SORTING OF HERRING

By ROGER RICHARDSEN and KJELL O. PETTERSON

TROMSØ, NORWAY, MAY 1988 : 42 PAGES.

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Abstract:

This report is a summary of the development of prototype electronics and mechanics for sex sorting of herring. Three different prototypes (electronics plus mechanical equipment) are described:

1) manual sorting, 2) sorting on conveyor belt and
3) sorting using fully automatic filleting machine.

In view of the current situation, the possibility of supplying sorted roe herring is considered the best use of the sorting equipment. Financial calculations indicate that sex-sorted herring fetch up to 54 % higher prices, depending on the degree to which the cost of raw material for the sorted milt herring is debited to the account for roe herring.

Key words:
HERRING
PRODUCTION
SEX-SORTING

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FOREWORD

This report is the final documentation of the project "Development of electronics for sex-sorting of herring". The project was one of several projects under the programme "Industrial processing of herring for consumption" financed by the Fisheries Research Council of Norway and "Efficiency measures" under the fisheries agreement between Norges Fiskarlag and the Government.

In this work, FTFI has given particular priority to the development of recording and measuring techniques. The present report will therefore, to a significant degree, be a documentation of the development of the electronics. The significant and extensive work which went into the development and testing of mechanical equipment in connection with the measurement/recording unit will not be reviewed in detail here. TRIO Engineering in Stavanger was an important collaborator in this work. Much of the practical testing was carried out at Romsdal Havprodukter in Harøysund but, later on, also at a number of plants along the coast.

FTFI was also given valuable support and guidance by the reference group appointed by the Fisheries Research Council of Norway. The group consisted of the following:

Alf Asbjørnsen	Directorate of Fisheries, Quality Control Division, Bergen.
Svein Eikje,	Feitsildfiskernes Salgslag, Trondheim.
Helge Johnsen,	Nordic Group A/L, Trondheim.
Jan A. Lem,	Firda Canning, Måløy.
Arne Johannessen,	Noregs Sildesalslag, Bergen
Jan Schøpp,	Norsk Pelagisk Fisk A/L, Stavanger.
Bjørg Ullsaker,	Norges Fiskeriforskningsråd, Trondheim.

Feitsildfiskernes Salgslag of Noregs Sildesalslag also contributed financially to this project.

FTFI would like to thank all for their positive cooperation.

SUMMARY

The project "Sex Sorting of Herring" was part of the herring programme "Industrial processing of herring for consumption" financed mainly by the Fisheries Research Council of Norway (Norges Fiskeriforskningsråd).

Previous market analyses have shown that Japan could be a potential buyer of both round herring and herring roe from a growing stock of Norwegian spring-spawning herring.
FTFI therefore started the development of equipment which could effectively separate the roe and the milt herring.

This report provides a rough summary of the development of prototype electronics and mechanical equipment for sex-sorting of herring. Three different prototypes are described (electronic plus mechanical equipment):
1) manual sorting, 2) sorting on conveyor belt and
3) sorting using fully automatic filleting machine.

In light of the current situation, the possibility of supplying sorted roe herring is considered the best use of the sorting equipment. Financial calculations indicate that sex-sorted herring fetch up to 54% higher price, depending on the degree to which the cost of raw material for the sorted milt herring is debited to the account for roe herring.

So far, there has not been much experience with commercial production of roe herring. However, there is a known demand for this product and prices of up to 100 percent higher than those for unsorted herring have been offered. This clearly indicates that sex-sorting of herring may be a quite timely production alternative.

INTRODUCTION.

In the beginning of the 80's the stock of Atlanto-scandian herring was again increasing after heavy overfishing in the 70's. Interest in production and new markets increased in step with optimistic resource forecasts. FTFI carried out several analyses of traditional markets, at the same time as possible new markets which could provide a basis for the best possible total utilization of the resource were examined. The possible use of the "by-products", roe and milt, were particularly looked at. Japan, with its great consumption of herring roe, stood out as a market of great interest to the Norwegian industry.

Whole roe sacs from herring preserved in brine ("kazunoko" in Japanese) have enjoyed a stable market of a good 10,000 tonnes. In addition, an increasing amount of frozen "roe sacs" is utilized as raw material for various roe products. "Loose herring roe", in the form we know from our export of capelin roe, also has a market here, but in more limited quantities. These roe products have been rather lucrative exports for Canada and the U.S.A. in particular.

Norway has exported such roe only in limited quantities, primarily due to the low supply of acceptable quality roe - while, on the other hand, the export of round frozen herring

to Japan has become an increasingly more significant part of our total exports. A modest amount of frozen herring was exported in 1982; this increased rapidly to about 17,000 tonnes in 1985. In the last two years this amount has levelled out to just under 20,000 tonnes.

These conditions have, to a great degree, brought to the fore the need for equipment which can sex-sort large Norwegian herring, not least because closer studies of the Japanese market have shown that there is a potential for supplying sex-sorted round herring to the consumer herring market - in addition to the already existing markets for roe. In other words, from a processing technology point of view, there is a need for equipment which can sort roe herring from milt herring to: a) supply whole roe herring or b) remove the roe from roe herring (whole roe sacs or "single roe").

Herring milt also has its special markets and application. Canned herring milt used to be a relatively large export item to England.

5.

Whether this will be the case again, is somewhat uncertain. But, first and foremost, many interesting things are happening in biotechnological research which may lead to milt herring becoming a product of interest.

Nucleic acids (DNA), which can be extracted from herring

milt, are in demand in the pharmaceutical industry as well as in the cosmetics industry. In addition, in the fight against AIDS, it has been found that Azeto-thymidine (produced from nucleic acid preparations) has a retarding effect on the course of the disease - which, in future, may make herring milt a raw material in great demand.

On the whole, there appears to be a potential for additional returns in being able to sex-sort herring and in this way take advantage of market possibilities inherent in the by-products.

The desire for equipment for sex-sorting of herring is not of recent date. Earlier, there was a special market for smoked herring with roe in the countries around the Mediterranean[1]. The higher price obtained by being able to offer a supply of herring containing mostly herring with roe made manual sorting profitable. This was done by several persons squeezing the herring bellies and deciding whether they were roe or milt herring. Today, this method is not feasible, primarily because of the cost incurred, but also because there is a shortage of people with sufficient "fingerspitzgefühl" (that special "touch") for this type of work.

This market provided the impetus for attempts early in the

[1] Nygård, Rolf Olsen & Co., personal communication.

50's to develop mechanical equipment for sex-sorting of herring at Christian Michelsens Institutt in Bergen (Ref.1). The procedure was based on transilluminating the herring with "rays within the optical or visible spectrum...". The same principle for sorting is also used by a Canadian firm which developed its equipment to improve the supply of herring roe for export to Japan from British Columbia in Canada (Ref.2).

6.

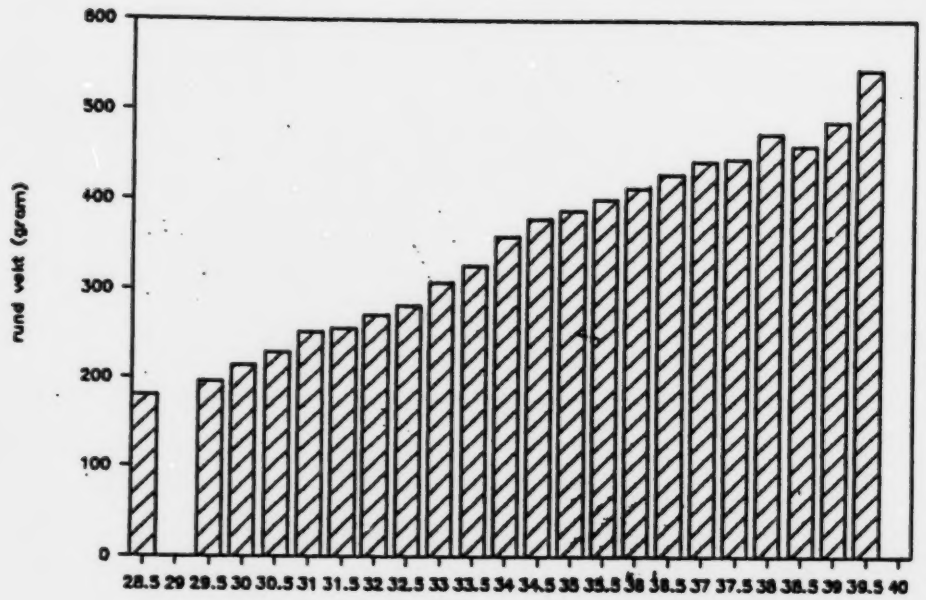
2. NORWEGIAN SPRING SPAWNING HERRING - SOME BIOLOGICAL CHARACTERISTICS.

Norwegian spring spawning herring (Clupea harengus) or Atlanto-scandian herring, as it is also known, is a type of fish which has a very great biological potential. In 1950, for instance, the spawning biomass approached 10 million tonnes. In 1954, the peak year for the Norwegian herring fishery, Norwegian vessels caught 1.5 million tonnes and this constituted 77% of the total Norwegian fish catch that year.

One reason for Norwegian herring being preferred in some markets is its size. In general, this particular herring becomes larger than any of the other herring populations - be it the Atlantic herring (Clupea harengus) or the Pacific herring (Clupea pallasii). The combination of quality and size has also contributed greatly to the success in the export of frozen herring to the Japanese market.

Weight vs. length of fish

Round weight (grammes)



Length (cm)

Figure 1: Round weight of herring in relation to length.

Source: Personal treatment of data from the Oceanographic Research Institute (Havforskningsinstituttet), Bergen.

The material was caught in Lofoten the 1st quarter of 1983. N = 427.

The data is not meant to illustrate a normal situation or a statistical average, but illustrate examples of the data collected.

WEIGHT VS. YEAR CLASS

Norwegian spring-spawning herring

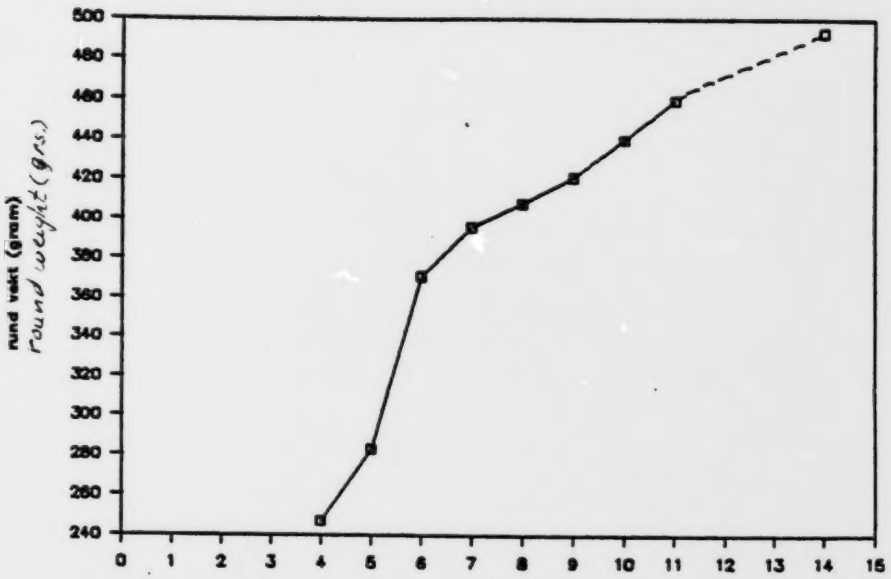


Figure 2. Herring size (weight) in relation to year class.

Source: Personal treatment of data from Havforskningsinstituttet, Bergen.

The material was caught in Lofoten the 1st quarter of 1983.

The Japanese market is primarily interested in herring over 300 grammes. We therefore used this large herring as material in our project. Since this market especially prefers the roe, the timing of sex-sorting is, of course, critical.

The primary target of our work in sex-sorting of herring was the Japanese market for herring roe. This market has quite definite product quality requirements: the roe must be mature, that is, it must be clear and transparent and have the proper texture. This is only obtained with roe caught in a relatively limited time period prior to spawning. Normally, mature roe will be found in herring where the percentage of roe is more than 16-17.

8.

However, sex-sorting based on Norwegian winter herring has, at present, its most promising potential in the sorting of consumer herring intended for the Japanese retail market. This herring is grilled whole in restaurants or in private homes, and roe herring is preferred to milt herring. The Japanese consumer is willing to pay a higher price for guaranteed roe herring than for unsorted packed herring (Ref. 3 and 4).

The Figure below shows the development of roe over the year.

Development of roe content in herring

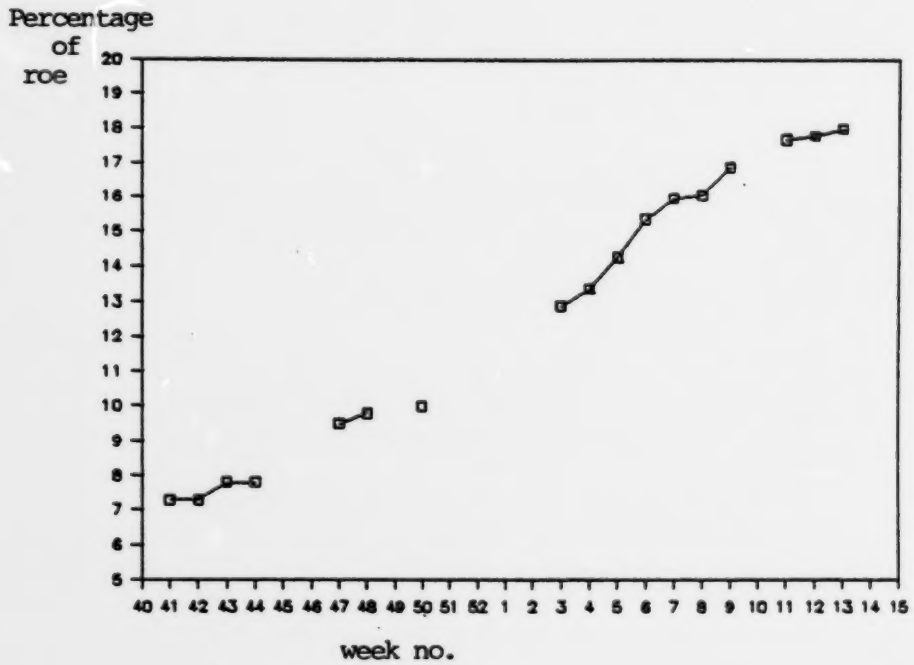


Figure 3:

1) Percentage of roe = $\frac{\text{weight of roe}}{\text{total weight of roe herring}}$ * 100

Source: Personal treatment of data from commercial catches in Lofoten and Vesterålen, fall 85/winter 86.

As can be seen, the development of the roe begins rather early in the fall. Around the turn of the year the percentage of roe comes up (10 percent). Normally, spring spawners will

WEIGHT OF ROE VS. LENGTH OF FISH

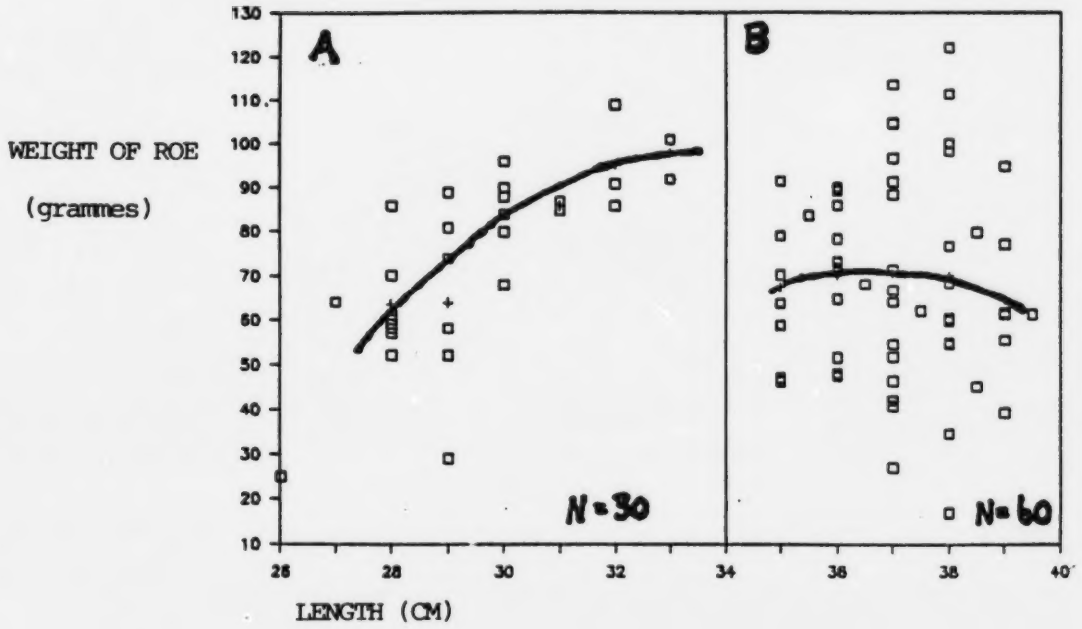


Figure 4: Weight of roe vs. length of fish from two different catches on Buagrunnen, Møre and Romsdal, winter 86.

Source: Personal material from experiments by Romsdal Havprodukter, Harøysund.

Figure A shows herring just prior to spawning.

Date of catch: 29 February '86; Buagrunnen.

Figure B shows the spread of the weight of roe in herring where spawning has begun.

Date of catch: 13 March '86; Buagrunnen.

begin spawning from the latter half of February to around the middle of March. This may vary along the coast. Spawning may take place as late as the end of March, for instance, on Buagrunnen off Romsdal.

Since Norwegian winter herring is significantly larger than other types of herring, this will, of course, be reflected in the size of the roe. Above are shown two Figures which illustrate the relationship between size of herring and weight of roe. The material was herring with mature roe just prior to spawning.

10.

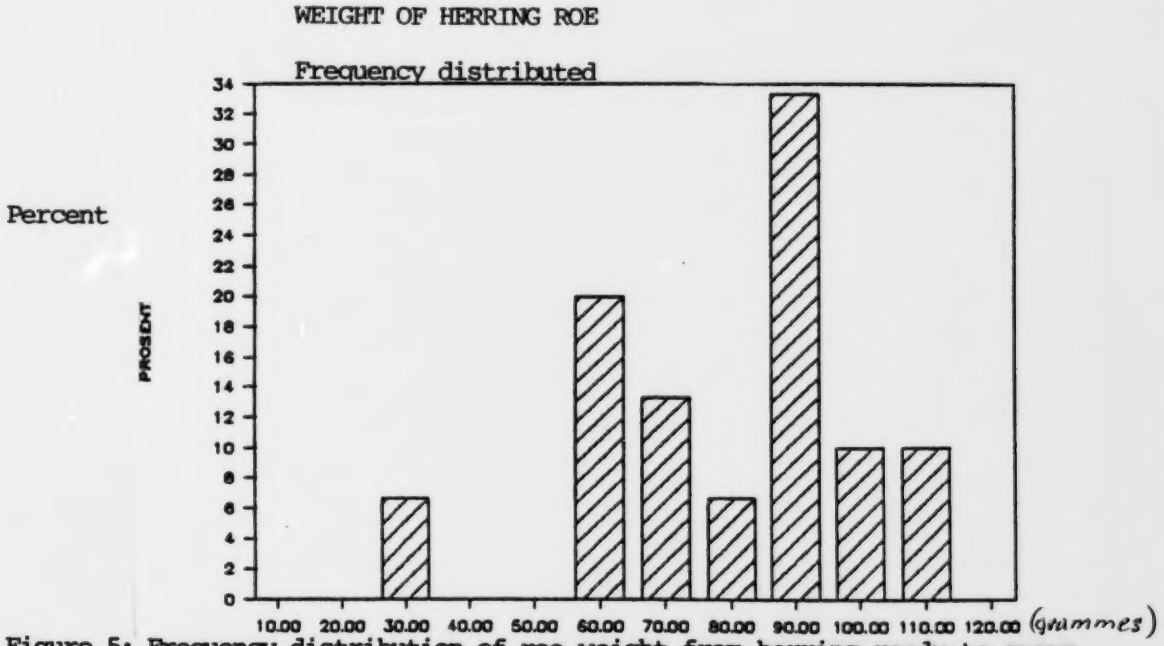


Figure 5: Frequency distribution of roe weight from herring ready to spawn.

Date of catch: 29.02.86. N = 30.

3. ELECTRONIC SYSTEM

As mentioned in the introduction, the first experiments in the sex-sorting of Norwegian spring spawners (herring) were carried out based on previously tested systems developed by, among others, Chr. Michelsens Institute and Neptune Dynamics, Canada. These systems were based on visible light, that is, a 250 W incandescent bulb. Our experiments showed obvious weaknesses in this system. First of all, the equipment was very energy-demanding and, secondly, the measurement results were very uncertain because they were easily influenced by other light sources in and around the measuring devices.

Despite some improvements with regard to energy and better components (among other things, lamps with narrower emission sprectra), the practical measurements were not satisfactory. Therefore, at the same time, other less energy-demanding frequencies in the light spectrum were looked at. And finally, it was decided to carry the experiments further by using equipment in the infrared range.

3.1. Measurement principle.

The system is, as before, based on measuring the light transmitted through the herring, except that now it is based on light in the infrared range. Infrared light has good

penetration capability and is not influenced by other light sources in the visible field which may be on the premises in this industry. It quickly became evident that this was considerably more suitable.

Figure 6, curve 2, shows the range selected, and curve 1 the field visible to the human eye.
An incandescent bulb will also, of course, emit much radiation in the infrared range, but it uses too much energy. See also the old measuring system, curve 3.

As is evident from Figure 6, curve 2, a wavelength of about 940 nm was selected. Many inexpensive components are produced around this wavelength. This material, called Ga.As (Galium Arsenide) can, depending on the impurities with which it is doped, be specified for quite narrow wavelengths with high intensity. When the incoming light hits the herring, some will be reflected, some will penetrate and some will be both refracted and absorbed, that is, completely disappear.

13.

The refraction depends, to a great degree, on the wavelength, that is, the colour of the light. The poorest result is obtained in the blue spectrum. Therefore, the red region is preferable.

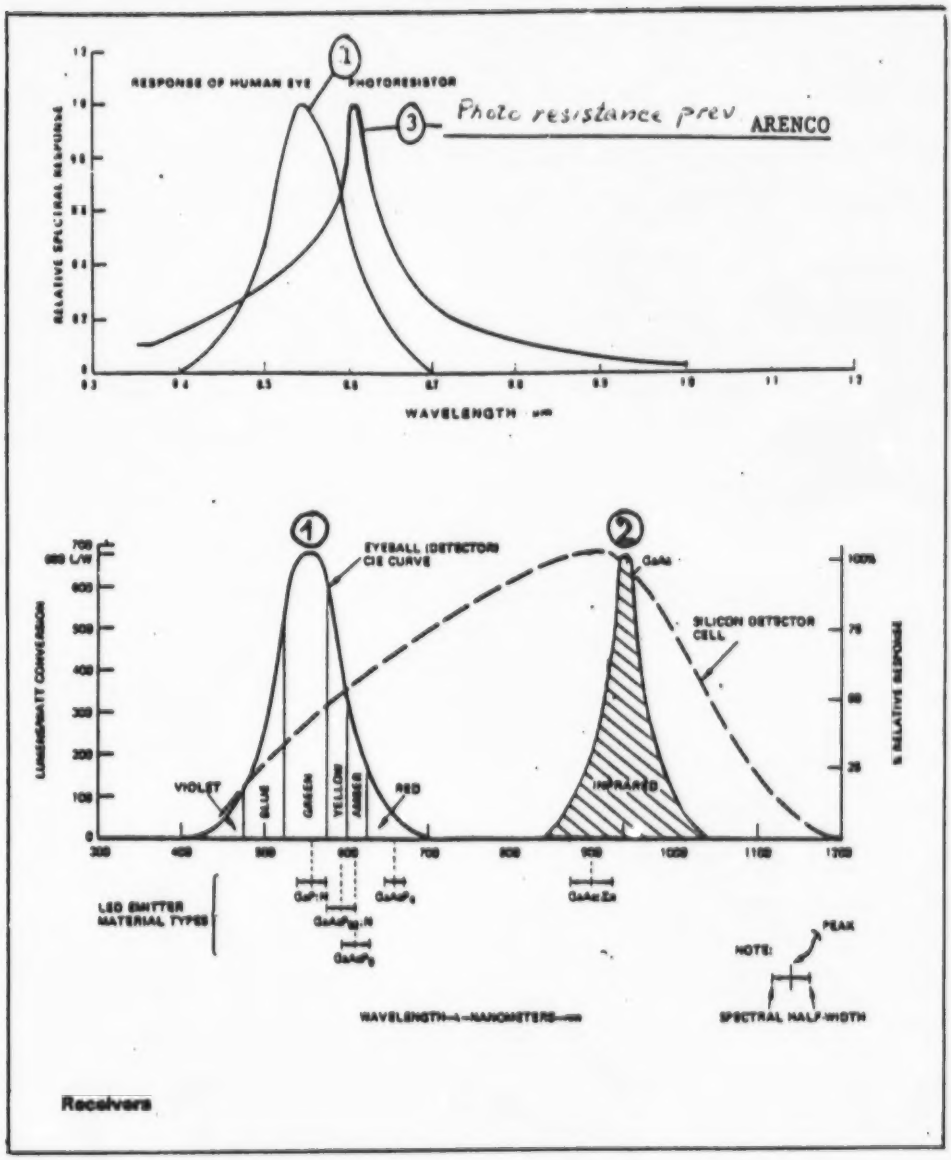


Figure 6: Curves for the selection of wavelength for light source.

Table 1, Figure 7, shows measurements carried out on light and dark roe compared with the characteristics of an ordinary incandescent light. Here it is particularly evident that absorption is least around 450-700 nm (visible field), but that it again improves around 940 nm. It must be regarded as a trend and not as an exact measurement of the spectral accuracy of the photomultiplier used here. It is further evident that red roe does not allow light to penetrate as easily as light roe. This can be considered a filter effect.

Table 1	Intensity		
Wave length	Incandescent light		
	Uncovered	Red roe	Light Roe
455 nm	110	-	-
600 nm	28	-	-
740 nm	53	17	40
940 nm	30	10	23
1000 nm	53	17	40

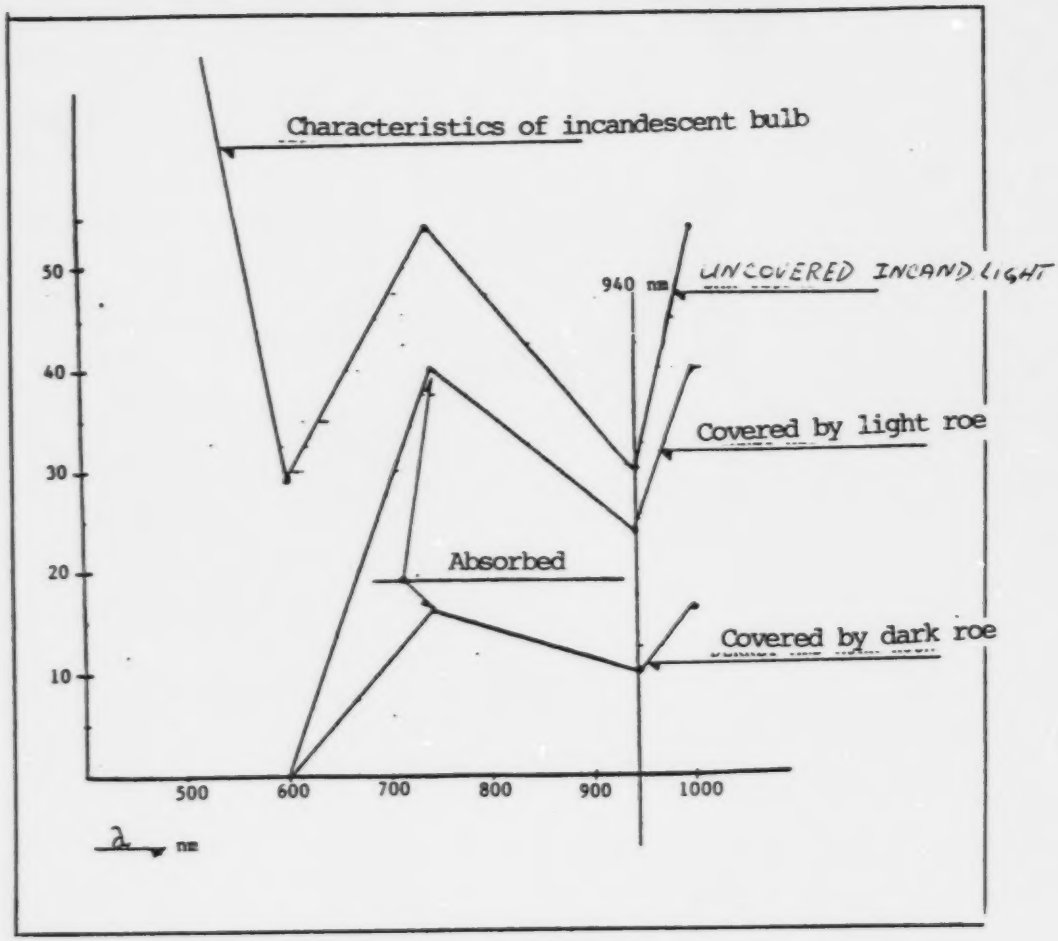

Characteristics of incandescent bulb
940 nm
UNCOVERED INCAND. LIGHT
Covered by light roe
Absorbed
Covered by dark roe
50
40
30
20
10
500
600
700
800
900
1000
λ nm

Figure 7.

3.2. Electronic system

The design of the system is shown schematically in Figure 8. It is mainly designed around a frequency phase locking system where, in brief, only the correct channel and frequency recognize each other. In other words, several systems can be placed next to each other without affecting individual measurements. See also Chapter 4.2 which describes how the system was tested by simultaneously recording six parallel channels and, in addition, where two systems per channel were used.

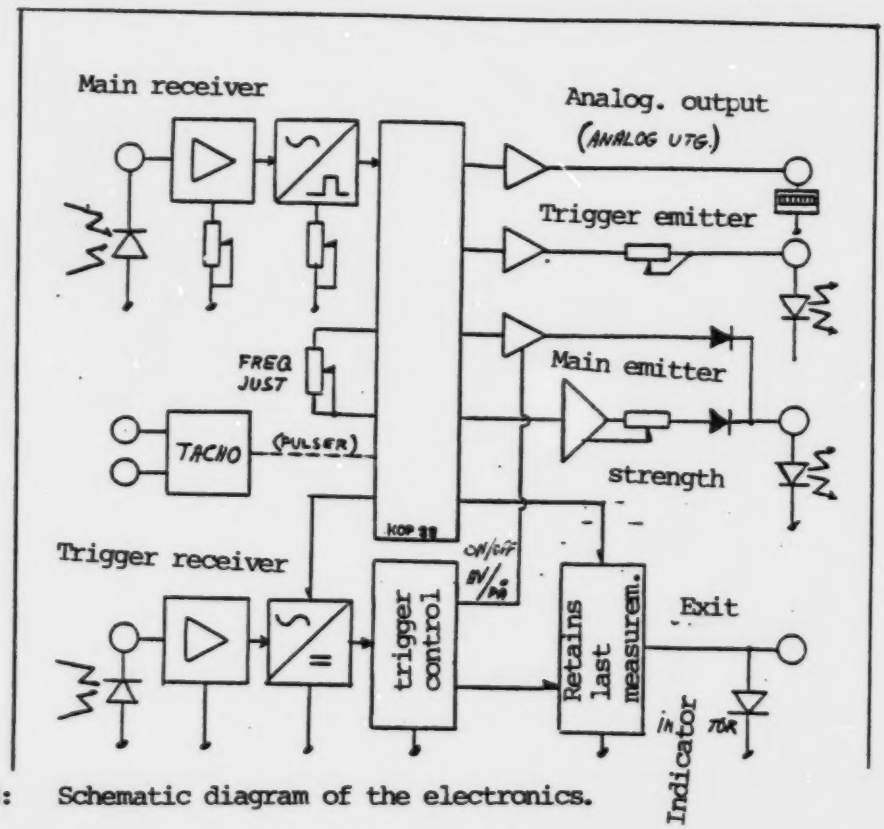


Figure 8: Schematic diagram of the electronics.

At an early stage, components for the sensors were selected which had been tested by another industry and also found to be very well suited to our environment.

Figure 9, curve A, shows the characteristics of the emitter diode with regard to intensity, in relation to the angle of aperture and with an emittance strength of 100 mA, while curve B shows the portion of the spectral region for which the equipment is best suited, that is, around 940 nm, as previously described.

16.

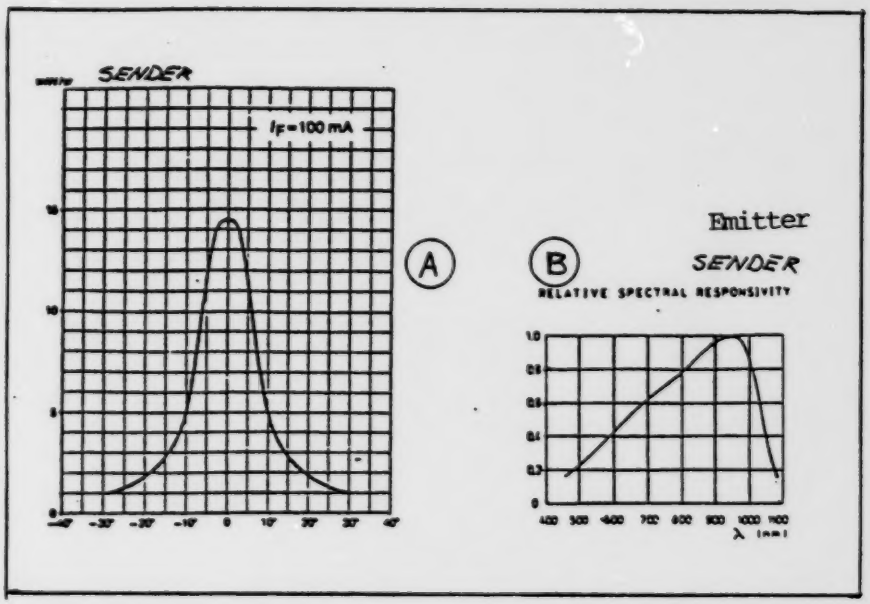


Figure 9: Characteristics of emitter diodes

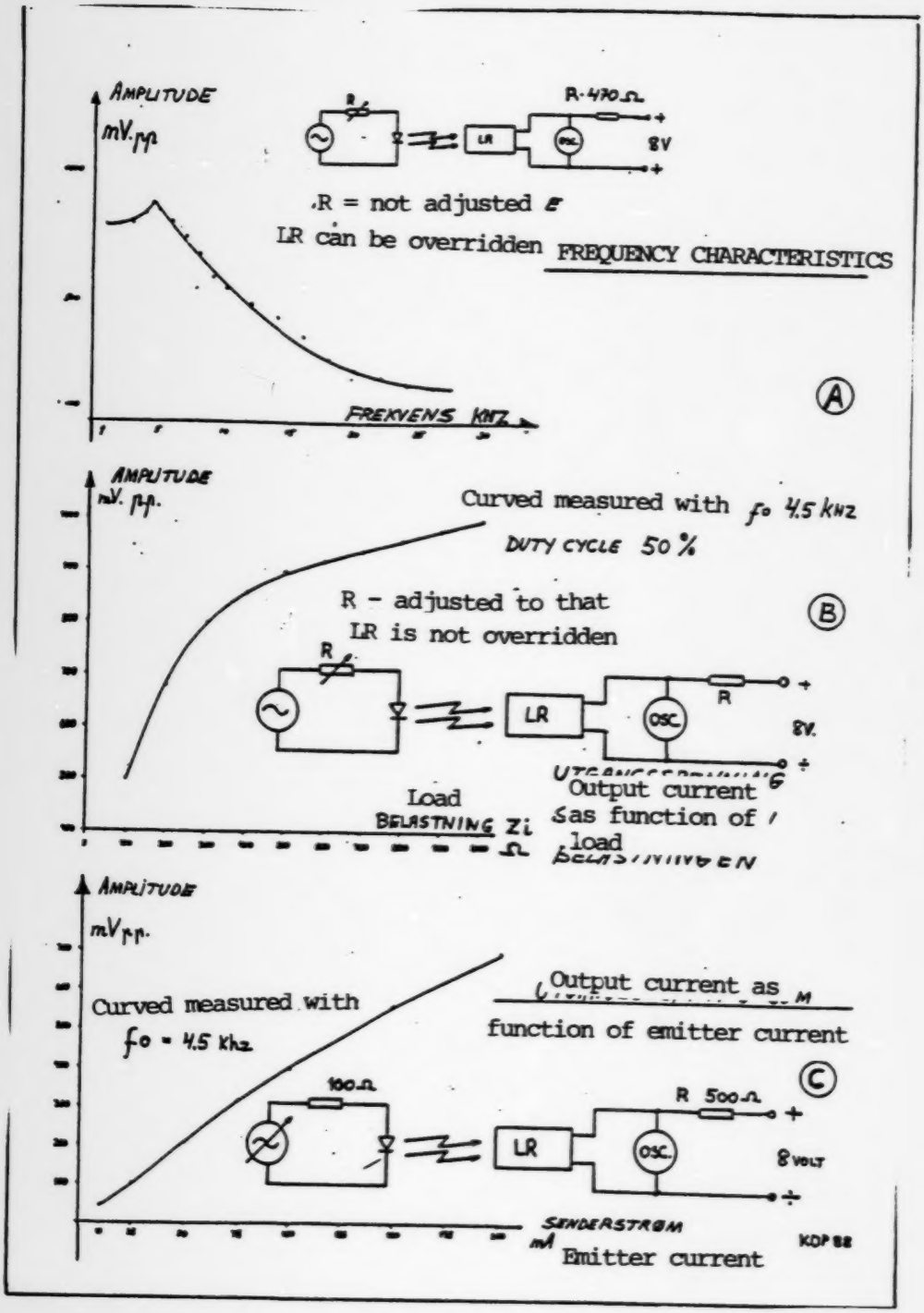


Figure 10. Characteristics of detector diodes.

Figure 10 shows some measurements on the detector diode itself with its different parameters. The first curve, A, shows optimal frequency to be around 4.5 - 5 kHz. Curve B shows its sensitivity to the resistance R when output from ?=R is an open collector and, finally, curve C shows the output at increasing emitter current, shown here up to 200 mA.

3.3 Method of operation.

At the selected wavelength, the emitter diodes are pulsed by a given frequency. When this is received, the signal is amplified, scaled and compared with the emitted signal. If it agrees with the light emitted, that is, the light penetrated the herring, then there is roe. This means that roe transmits the light, while milt absorbs it, that is, the light does not penetrate at the particular signal level.

This is then fed to the output which will be stable after each measurement, and remain static as long as the same type of fish is being measured, for example, only milt herring.

There is also a "trigger" system which, in addition to the measuring system, plays a part in controlling the whole measuring sequence (see Figure 11, Table II). This sequence

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diagram describes the operation of the previously mentioned systems, roe and milt, respectively. The measuring system is here marked 1 and the trigger system 2.

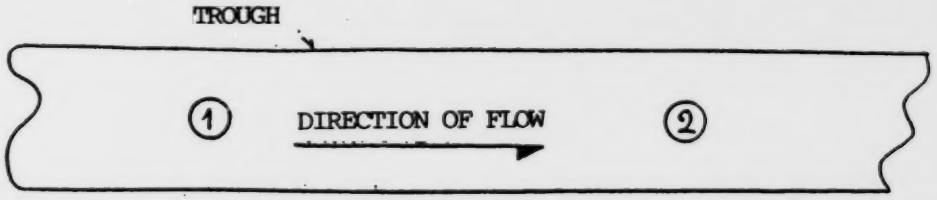


Figure 11. Table II	Roe herring		Milt herring		Actuator	
Recording frequency	Measurer 1	Trigger 2	Measurer 1	Trigger 2	Output Roe	Milt
1 No herring	1	0	1	0	-	-
2 Herring passes measurer 1	0	1	0	1	-	-
3 Herring moves on	1	1	0	1	-	-
4 Herring passes trigger 2	1	0	0	0	1	0
5 Herring moves on	0	0	0	0	-	-
6 Herring leaves 1	0 / 1	/ 0	0 / 1	/ 0	-	-
7 Herring leaves 2 is out	/ 1	1 / 0	/ 1	1 / 0	-	-

Measuring system		Output/Actuator	
1 =	On	1	= Roe herring
0 =	Off	0	= Milt herring

Figure 11 Sequence diagramme

See also drawing in Figure 14, which shows the placement of the system. The schematic drawing of the electronic system also shows an input with a pulse generator/pulser (TACHO). This is a supplement for possible integrated recording of some other parameters, for instance, size, number, rate of speed/capacity, etc..

An output is also shown, which can show analogous values which could be used to display the degree of maturity of the roe and thereafter make a selection according to these parameters. However, these are items which, for reasons of time and cost, have not been further developed. The development of measuring systems has, at all times, had a practical and applicable character, so that the primary tasks were given priority in the industrial testing of the systems.

Some of these different experiments, where the electronic measuring system was tested in combination with different mechanical strategies, will be described in the following chapters.

4. TESTING OF PROTOTYPES

The demand for capacity is generally important to most industrial production in Norway. High labour costs encourage economies of scale in production and promote mechanization of work operations. FTFI therefor stressed that the overall answer to sex sorting of herring should have high capacity and at the same time should be capable of functioning independently of any specific make of filleting machine - not as, for instance, the Candian system which was specifically developed for one of Arenco CIS/CIF filleting lines.

4.1. TRIO 1

Therefore, in the winter of 83/84 Trio Maskinindustri A/S, Stavanger[2], was contacted concerning cooperation in developing mechanical equipment in conjunction with electronics for sex sorting of winter herring. The goal was first to develop a prototype which could later be put into mass production.

---

[2] The firm Trio Maskinindustri A/S went bankrupt in March 1987. A new firm, TRIO Industrier A/S/, was established in April of the same year and continued the work which Trio Maskinindustri had begun.

Basically, requirements placed on this first experimental model from Trio Engineering (henceforth called Trio 1) were:

- orientation of the herring, so that they move head first;
- the herring must be separated (no overlapping);
- good capacity. Several independent troughs (4);
- it must be possible to measure the herring regardless of which way the belly lies;
- roe and milt herring must be separated according to the signal sent by the electronics (pneumatically controlled flap).

The first model - Trio 1 - was an enlarged version of Trio's series production model for orientating sardines and brislings.

The model consisted of the orientator, the chute and pneumatically controlled flaps (see sketch, Figure 12).

Description of "Trio 1".

The orientator (1) slides back and forth on tracks. The back-and-forth motion is generated by an arm and an eccentric wheel mounted on an electric motor. The speed of the motor is

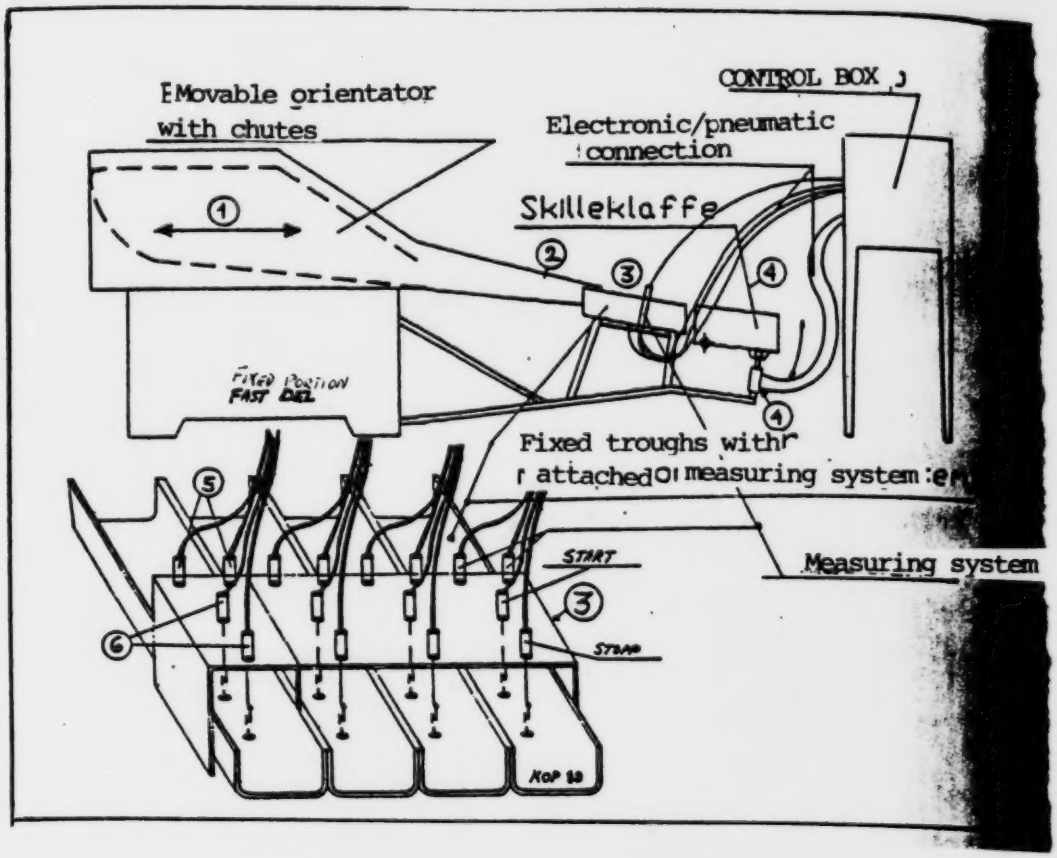


Figure 12: Sketch of TRIO 1: Prototype for sex sorting of herring.

adjustable. The herring is fed in over the top of the orientator which is covered by a friction mat. The back-and-forth motion of the orientator and the herring grate causes the herring to orient themselves lengthwise and move in the direction of the head.

The herring was guided in by water (low friction) and angularly positioned plastic channels (2) moulded in one piece with the orientator and therefore had the same back-and-forth motion. The herring slid gradually over into stationary troughs where the sex recording and separation system was mounted (3).

The separation of milt and roe herring took place with the aid of pneumatically controlled flaps. The magnetic poles of the air valves (4) were actuated by 24-volt signals from the electronics.

23.

Only small modifications were made to the experimental model as long as it was used. The orientation principle which was used here appeared to function satisfactorily.
However, there were individual cases where two or more herring overlapped each other. This was because one channel received herring from two supply channels. The system was such that the herring which went "backwards" and into one of the channels could "meet" a herring which went "forward" into another channel where they merged into a common channel.

The measurement system (5 and 6) was mounted on the stationary troughs. This was installed by FTFI and modified as experience was gained during the experiment.

In the beginning, no requirements were set for the herring bellies to lie against the same side through the measuring system, necessitating emitter diodes on both sides of each individual channel. The emitter diodes were moulded into the bottom of the channel, while the receiver diode was mounted in a bridge over the channel (see 5, Figure 12). Originally, 3 parallel emitter diodes were mounted in each side of each individual channel, but the final result was just one on each side per channel. Attempts were made to install the emitter diodes so that they sent signals towards one common receiver for each channel. In practice, it was found to be difficult to fix the emitter diodes so that the emission rays had the correct angle to hit the receiver with an optimal signal.

Since the speed of the herring passing through the measuring system was not controlled, the system had to be expanded to include a "trigger" system, which could record when a herring passed over the emitter diodes so that measuring could commence and when recording should cease, in other words, a "start/stop" function (see 6, Figure 12).

Technical summary Trio 1.

The orientator functioned satisfactorily. There were instances when herring overlapped each other, but this could

easily be resolved. The first channels where the measuring system was mounted were a bit too wide causing the herring to pass "diagonally" across the measuring system or along one side. Since both emitter diodes then would not be covered, errors in measurement would occur.

To improve this, liners were added to the sides, but this occasionally caused the largest herring to get stuck and block the channel.

There were also some difficulties because the sorting flaps had their storage near the troughs which caused some fast-moving herring just to go straight ahead. This, too, caused measuring errors.

After extensive testing using this experimental model, it was decided, in consultation with Trio Maskinindustri A/S, to build a new prototype based on the same main principles but eliminating some of the causes of errors which had been experienced with the first model.

4.2. Technical design of TRIO II with 6 channels.

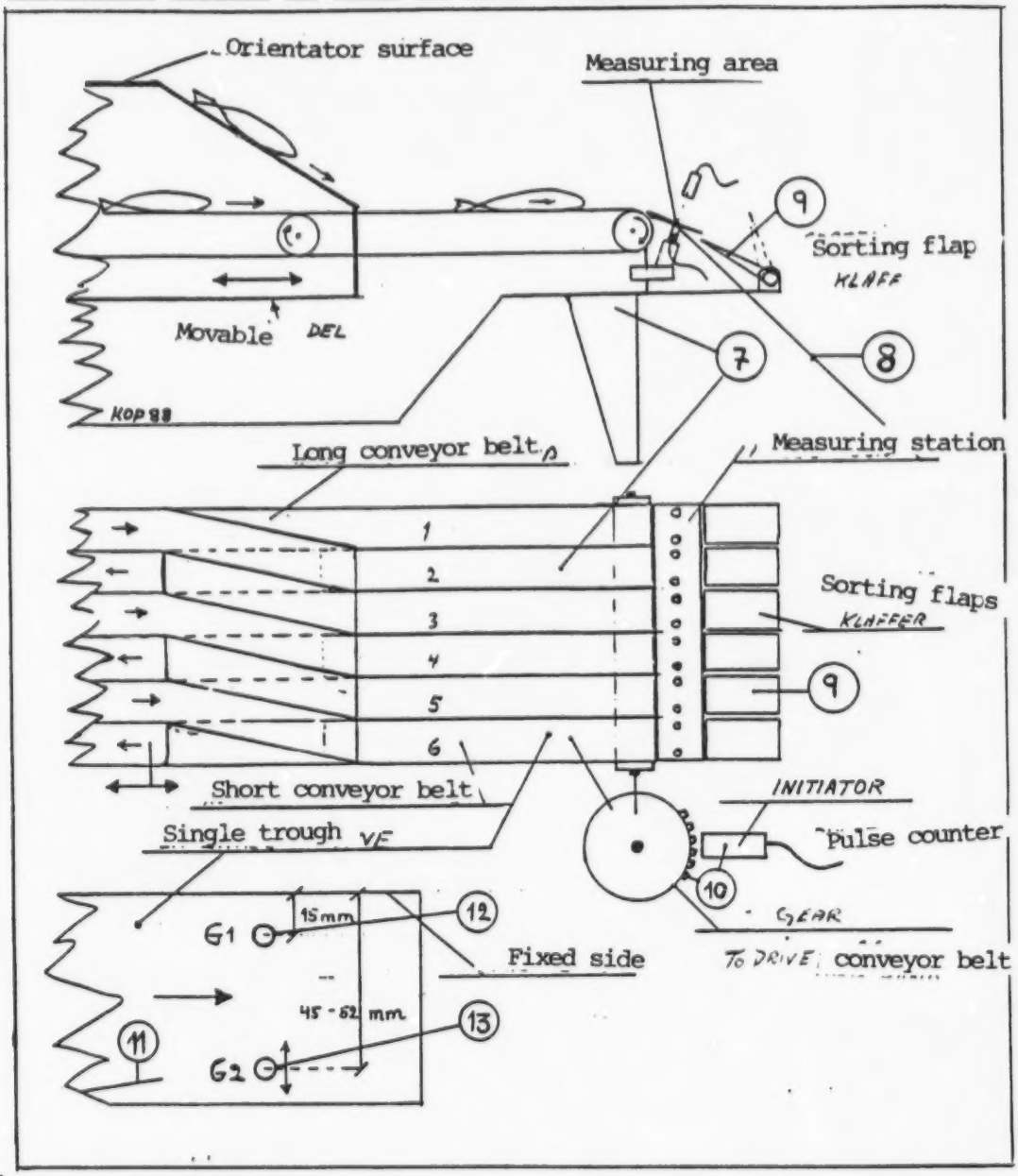


Figure 13:

Sketch of TRIO II.

The orientation principle itself was retained as it had been used on Trio I. The back and forth motion causes the herring to go through the six channels, three forward and three backward. These were made differently from Trio I in that the channels emptied on to separate outgoing conveyor belts in the horizontal plane, in contrast to the backwards- and forwards-travelling channels merging into one. This solved the problem of the herring coming down in the front falling on herring coming from the back channel (see 7, Figure 13). The outgoing conveyor belts were divided into two, one front and one back portion. Each of these endless conveyor belts had a width of about 100 mm and were separated by steel edges. The mounting for the electronics was located between the front and back conveyor belts, (see 8, Figure 13).

It turned out that the back belt (not shown in the Figure) was unnecessary as the herring slid very well over the measuring station and directly on to the sorting flaps, (see 9, Figure 13.

One of the problems this prototype was meant to eliminate was centring or exact positioning of the herring on the conveyor belt. This should have been solved by plastic control flaps. However, it was found that this was not a good solution, so they were removed at an early stage. Larger herring got

stuck. To even out the gap between the conveyor belts, a PVC plate was inserted. However, it was also removed at an early stage as some herring lost speed over it and often stopped altogether, as previously described. Another reason for the herring stopping was that the outermost conveyor belt was located lower and therefore did not "get hold of" the herring. The pneumatic control flaps were mounted at the end of this outermost conveyor belt in the same manner as in TRIO I.

An inductive indicator was also part of this electronic equipment and it was located so that it could record the teeth of the gear (see 10, Figure 13) mounted on the driven shaft of the back conveyor belt. This recording would be used in connection with the trigger system to start and stop the measurement.

At the end of April 1985, the machinery was tested at Romsdal Havprodukter for the first time. The test resulted in a decision to modify the machinery further before using it for more extensive testing.

27.

The changes that were important were,first and foremost:

- the machinery had to be equipped with an elevator to supply the sex sorting machine with herring in a continuous and controlled manner;

- the rate of speed of both the orientator and the conveyor belt had to be adjustable;

- primarily it should be possible to turn the herring so that the belly always lay against one side. If this was not possible then the positioning (centring) would have to be much improved;

- it should be possible to adjust the distance between pairs of diodes on the individual conveyors (according to herring size) if the measurements should be taken regardless of which way the belly/back lay in each trough;

- the transition between conveyors would have to be improved so that no herring could become stuck.

Modifications

In summary, the technical modifications carried out during the summer of '85 were as follows:

- control flaps were installed on one side of each conveyor belt. This was to guide the herring towards one of the sides. (See 11, Figure 13);

- one of the emitter/receiver diode sets was fastened 15 mm from the edge toward which the herring was directed (see 12, Figure 13). The other diode set could be adjusted to between 45 - 52 mm from the same edge, automatically, if necessary (see 13, Figure 13). This was done to be more flexible with regard to size of herring.

  These distances were calculated for the most optimal values as to where the roe sac would be regardless of which way the herring would lie.

- The short conveyor belt was removed, as previously mentioned, so that the herring could pass over the separator flap immediately after having passed the electronic measuring system.

Conclusion

Test runs showed that, with the present design of herring sorting machines, errors of 5% can be expected with a capacity of about 2.5 tonnes per hour.

28.

During testing, it was found that even when the machine was equipped with an orientator and automatic feeder one person was needed to ensure that no herring overlapped each other.

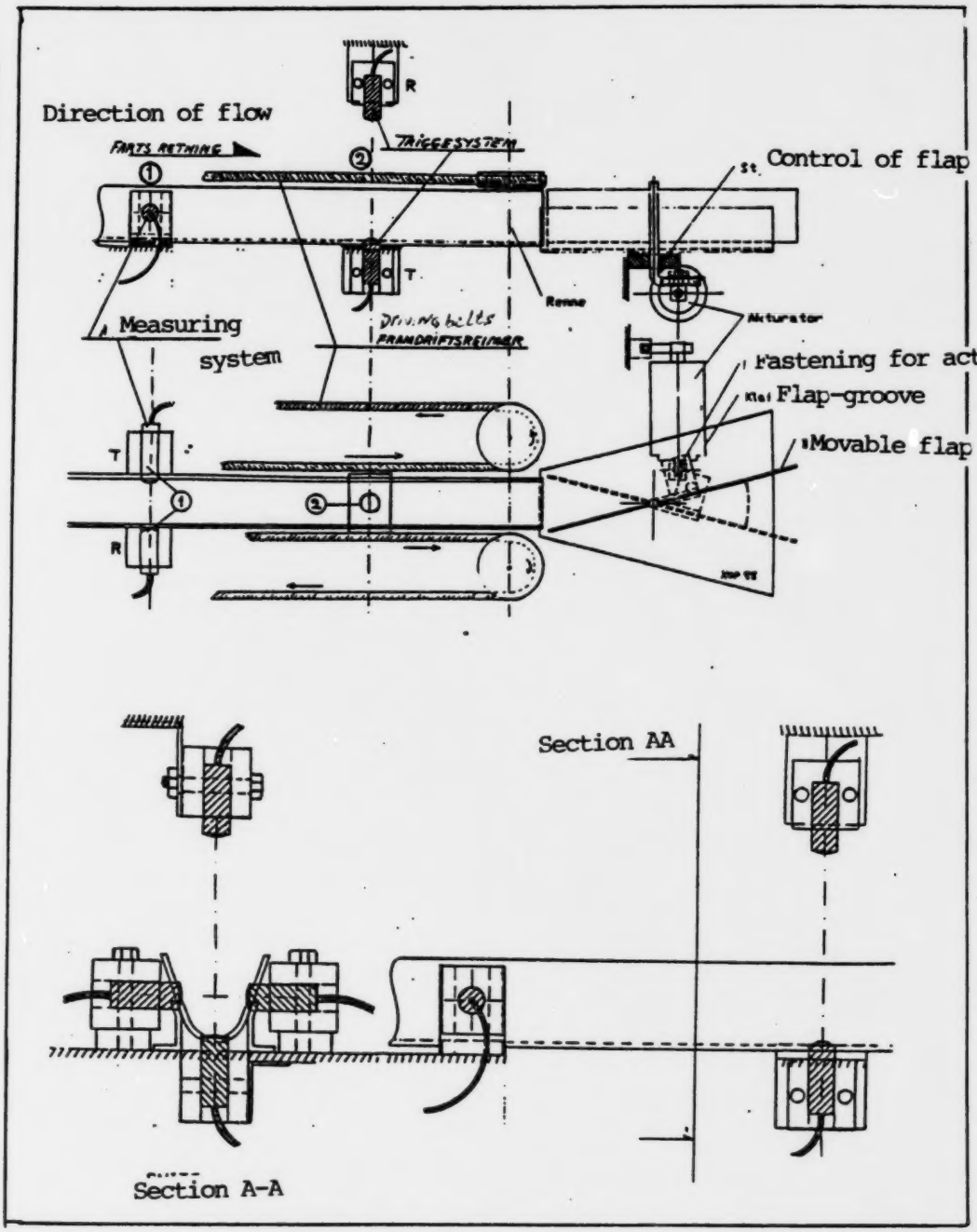
Such a line of herring will cause measuring errors, since it will appear as one continuous large herring where the first (herring) will determine the measuring results.

4.3 The Arenco model

Parallel with the Trio development of TRIO II, attempts were made, in cooperation with Romsdal Havprodukter and FTFI, to use an Arenco filleting machine for sex sorting.

In order to implement the experiment, the filleting knives had to be removed and replaced with a special groove through which the herring was directed. The existing forward driving belts were employed to move the herring forward.

The electronic recording system was mounted in the groove and a separate special separator flap was installed at the end of the filleting portion of the machine. See Fig. 14. The special feature of this design is that the herring is transported forward all the way through the groove with belly down. The herring belly fills the whole groove so that the risk of false signals is minimized. False signals may occur by signal reflections if the herring belly does not sit all the way down in the bottom of the groove, or if the herring goes through with the back down.



Figur 14 A og B

Figure 14 A and B.

Test results.

One test run on the "Arenco model" showed "no" errors in recording of roe/milt herring. On this machine the herring is moved along a groove with belly down. By having the belly always lie the same way only one emitter diode was needed, it was completely covered by the herring. Errors occurring as a result of reflected signals are then sharply reduced. Since this machinery is based on manual feeding of the herring, the capacity will be 50-60 herring per minute per operator.

Below are shown the results of a series where a total of 1,800 herring were run through the system.

Total no. herring	Sorted as roe herring	Sorted as milt herring	Milt in roe herring	Roe in milt herring
1,800	962	838	0	3
Percent error			0	0.3

This model, where we had optimal control of positioning of the herring, was found to function very satisfactorily.

The conclusion which could be drawn was that the measuring

equipment functions 100% accurately. Errors in sorting could be related to the mechanical equipment, not the electronic system.

Based on these results, it was decided, in consultation with Trio Maskinindustri A/S and the financiers (the reference group) to produce 5 in a 0-series based on the same principles as shown above. These were then offered to the then producers of Japan herring for commercial testing during the late winter of ´86. At the same time, FTFI worked hard to modify the filleting machinery at other producers for the purpose of commercial sorting. One model (from Trio) was placed on board a vessel for testing.

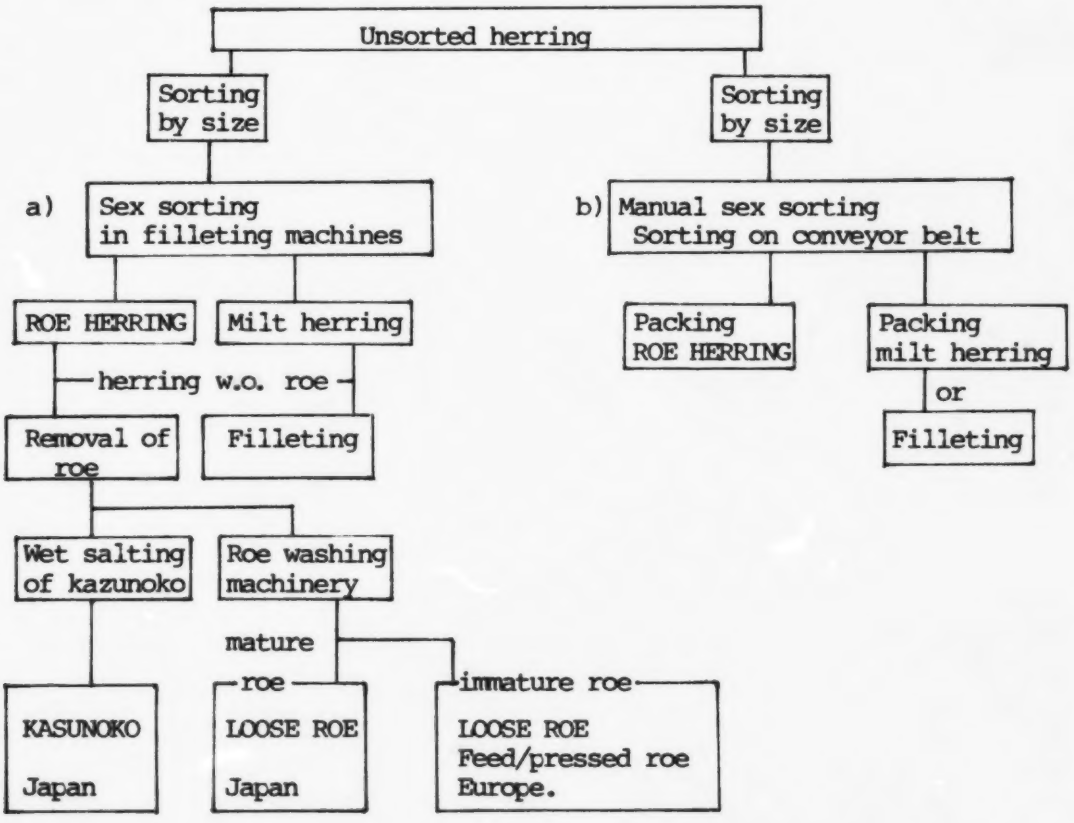
In total, about 10-12 such units were put into operation, but several of these were not utilized on a commercial scale due to lack of raw material of quality acceptable to the Japanese market.

5. COMMERCIAL SYSTEMS

Based on experience from various tests of mechanical equipment, and with a background in the knowledge of product demands placed by the market on the herring products in question, the conclusion arrived at was that electronics used in sex sorting of herring must be sufficiently flexible to be easily adapted to several different mechanical solutions, depending on the purpose of the production.

The Figure below shows alternative purposes of sex sorting:

a) Sex sorting for roe production b) sex sorting for consumer herring



One of the main reasons for needing several alternatives is that completely different requirements are placed on the handling of the raw material, depending on the purpose of sorting. For instance, in sorting roe herring for consumer herring it would be preferable to cause the least possible physical pressure from mechanical equipment. Sorting using the automatic feeder of the filleting machine could cause pressure and squeeze damage to the herring which are not acceptable to that market. Sorting on conveyor belt and distributing the herring to the individual packing stations, or alternatively, manual sorting during packing will, however, be alternatives which minimize such handling damage.

In production where the roe is removed from the fish this type of careful treatment is not necessary. But the demands for capacity will be greater and it may be appropriate to use high-capacity equipment.

Below is a more detailed description of the three different production alternatives where equipment for sex sorting is included in the production lines:

(1) sorting in filleting machine having automatic feeder;
(2) sorting on continuous conveyor belt;
(3) manual (stationary) sorting.

5.1 Sorting in filleting machine having automatic feeder.

The figure below illustrates an experiment carried by FTFI on a VMK herring filleting machine (Vestkusten Maskin & Kyl A/B, Gothenburg). However, the system is not specifically adapted to this make but could be adapted to most common types of herring filleting machines with attached automatic feeder unit[3].

33.

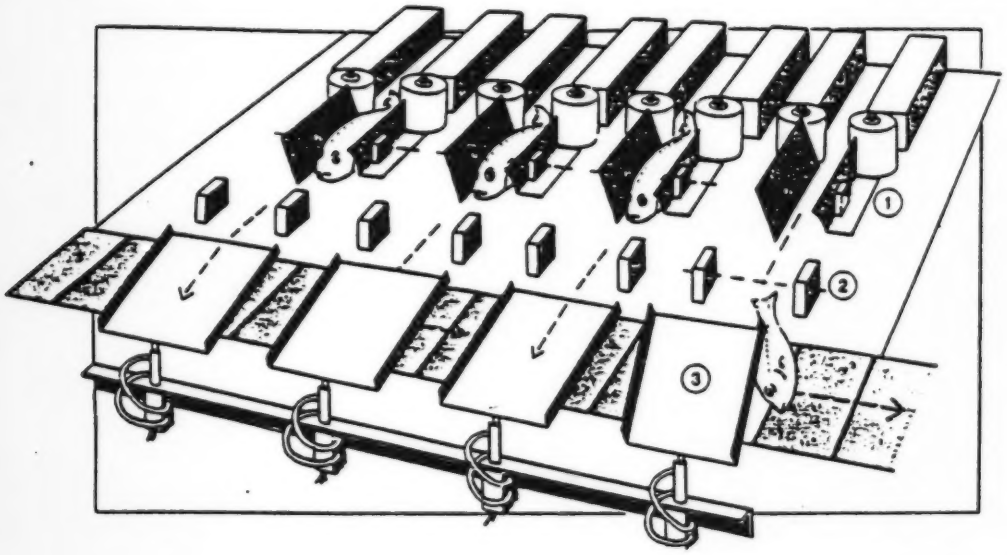


Figure 15: Sketch of location of electronics and mechanical separator unit when sex sorting herring using filleting machine.

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[3] In Norway, the most common machines are Baader (W.Germany), Norden (Sweden) and VMK (Sweden).

The advantage of this equipment is that existing technology, standard in many plants, is used. The sorting is here automatic with the same capacity as for ordinary production (butterfly or single filet), that is, about 230 herring per minute.

The results of the measurements are clearly dependent on orientation and positioning in the feeder unit being done correctly. In practice, some herring (particularly if the raw material is of uneven size) will not be turned belly down in a manner necessary for the herring to be in the right position in the filleting section. This will, of course, have consequences for the sex sorting insofar as the herring then will be measured through the back and result in the fish being classified as milt herring - regardless of sex.

34.

In correct sorting, the milt herring will automatically be moved to the filleting sections of the machine, while the roe herring will be guided over the feeding trays - either to another conveyor belt, or to a tub for later removal of roe.

5.2. Continuous sorting on conveyor belt.

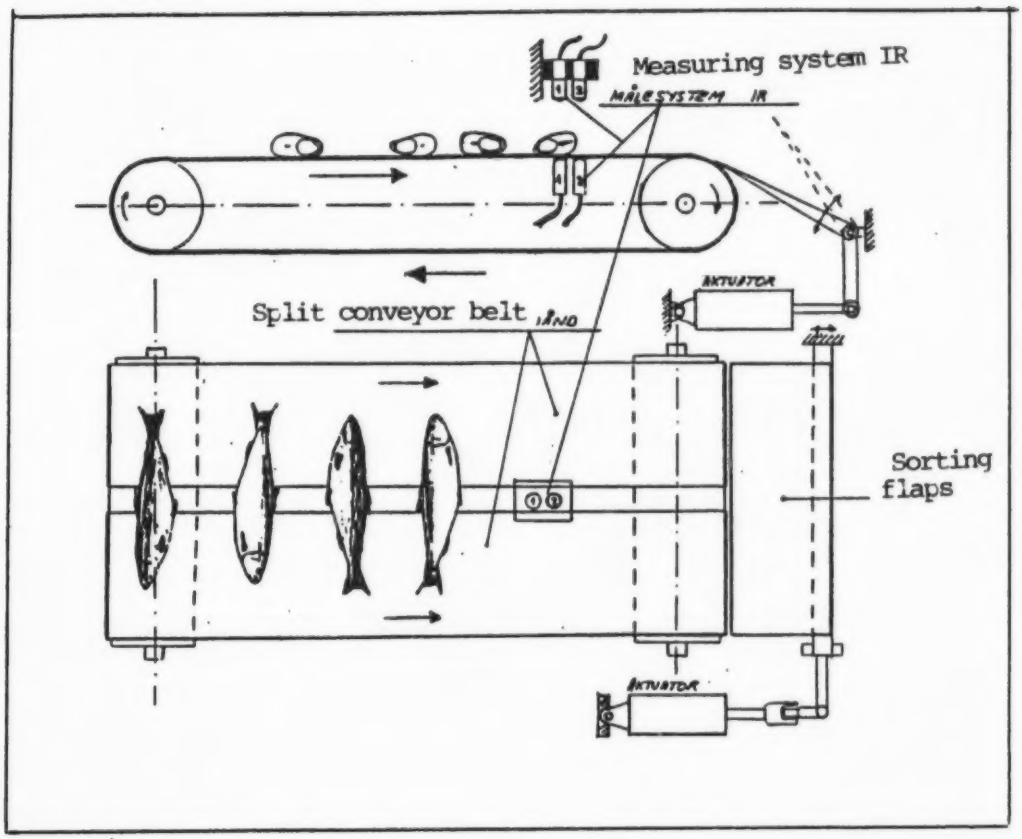

Figure 16: Sketch of prototype for sex sorting on conveyor belt.

5.3. Manual sorting.

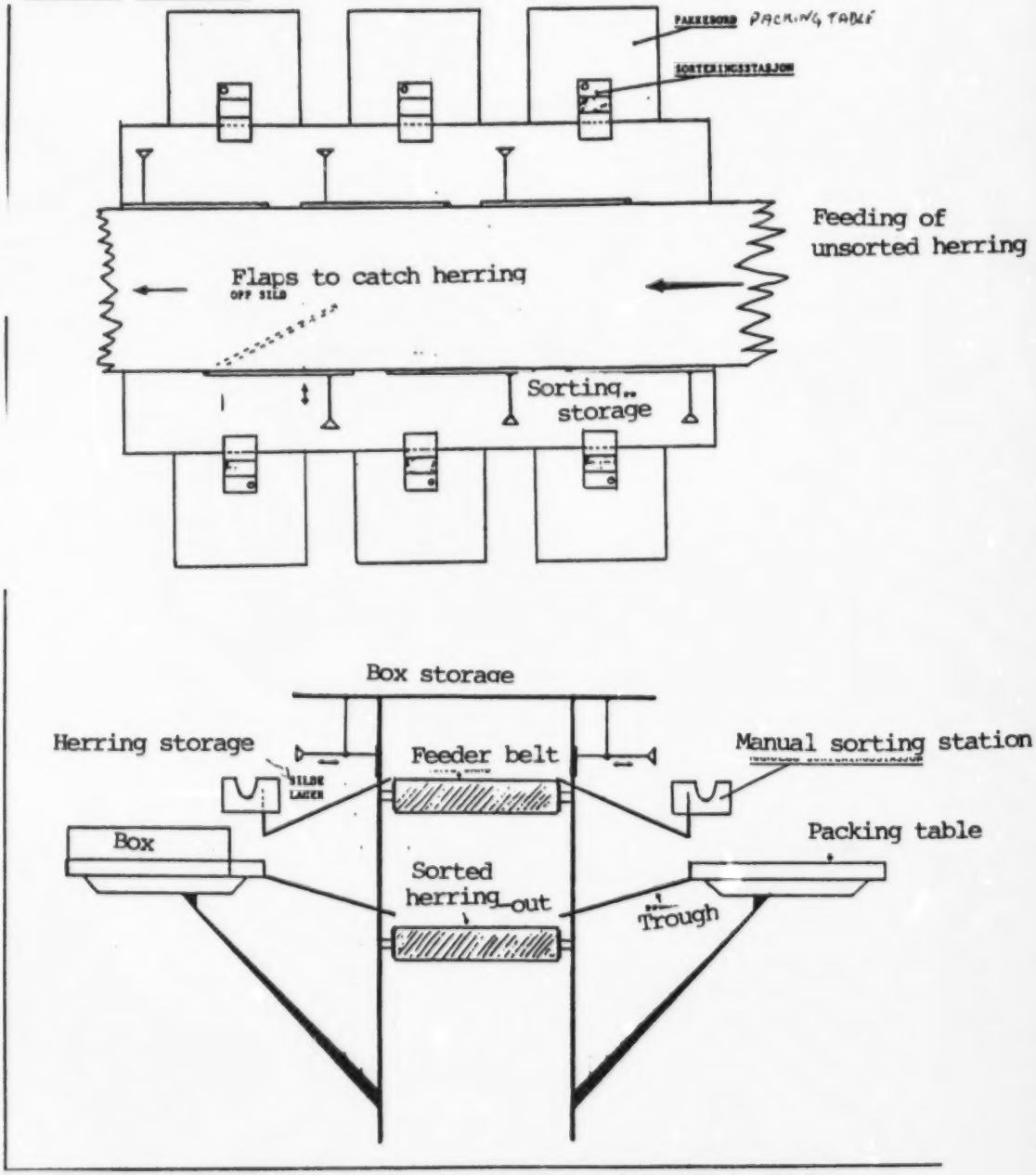

Figure 17: Sketch of layout for stationary sorting, at Norfisk, Svolvær.

5.4 Economics/profitability of sex sorting of herring.

The primary purpose of the whole project was to contribute to increased profitability through utilization of the herring resources. The market prospects have shown that there is clearly a potential for Norwegian herring in Japan and, to start with, also for herring roe[4]. In view of current conditions (supply of resources and market conditions) we feel that the most obvious potentials are in the supply of roe herring to the consumer herring market in Japan. Therefore, in the following, we particularly refer to financial forecasts for this use of the equipment.

Below is shown a computation for production of "Japan herring", that is, unsorted large winter herring packed with belly up and salted in 7 kg boxes. The figures indicate the cost of such production for the 1987/88 season and are primarily based on private recordings from several plants having such production. The computations therefore represent an "average plant", that means, there are plants with better or poorer production than shown here.

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[4] The Japanese market for herring and herring roe is more extensively dealt with in a separate report from the project "Industrial processing of herring for consumption.: See Richardsen (1988).

5.4.1 Computation of allowance to cover fixed costs - herring for Japan, packed belly up and salted.

Assumptions:

Raw material price	NOK. 220/hl	
	NOK 2.37/kg	
Hourly wages (incl. social expenses:)	NOK 85/hr.	
Selling price (FOB)		NOK 5.50
Cost of raw material (Yield: 98%)	NOK 2.41	
Freight to shore in well boat*	" 0.40	
Direct cost for wages:		
Sorting (by size)	" 0.20	
Receipt/packing/freezing	" 0.65	
Re-stacking/loading	" 0.07	
Packaging material (box + wrapping)	" 0.81	
Freezing costs	" 0.20	
Storage costs (incl. interest)	" 0.08	
Total costs		NOK 4.82
Allowance to cover fixed costs per kilo produced		NOK 0.68

* Well boat: A vessel specifically designed for the transport of live fish. Usually the hold is built as a basin or well with adjustable valves in the bottom and lower sides and circulation pumps to draw in and pump out sea water. The valves and circulation pumps are controlled from the bridge. The well is provided with a split well cover with sides, "resting" about 2/3 up the sides. Larger vessels (200-300 tonnes) also have a refrigeration system to cool warm summer seawater. Tr.

Comments on the computation..

The item "freight to shore" included in the computation is costs which the plant incurs when purchasing raw material directly from herring seines (over the side). Due to stiffer competition we know that some plants in Lofoten had contracts as low as NOK 25.- per hl, corresponding to NOK 0.27/kg, last season. If the catch is bought directly from the vessels, then this expense is eliminated.

"Sorting" is sorting according to size of raw material prior to packing. This is a very important function during production of consumer herring because the herring is sold by the piece on the market and the demand for uniform size is accordingly. The expenses shown here are for manual sorting. Expenses for sorting have become considerable, particularly now that the population consists of several different year classes (different sizes).

As for most fish production, the raw material constitutes the major portion of production costs - in this case 50%. Direct wages amount to slightly less than 20%, while packing amounts to a full 17 percent of the production costs. This is because consumer herring is packaged in small units and in boxes of

relatively expensive quality. This is necessary since the products often remain in this packaging until they reach the final consumer.

What, then, is achieved by supplying sex sorted herring instead of unsorted packaged herring? Below is shown a corresponding computations for the production of sex sorted herring using "manual sorting", see Chapter 5.3.

5.4.2. Computation of allowance to cover fixed costs - sex sorted herring:

This computation is based on the same assumptions as for unsorted herring:

Raw material price	NOK 220/HL		
	NOK 2.37/kg		
Hourly wages (incl. soc. expenses)	NOK 85/hr		
Selling price (FOB)			NOK 10.25
Cost of raw material (Yield: 50%)		NOK 4.74	
Freight to shore (well boat)		" 0.40	
Direct wage cost:			
Sorting (by size)		" 0.20	
Receipt/packing/freezing		" 1.30	
Restacking/loading		" 0.07	
Packaging material (box + wrapping)		" 0.81	
Freezing costs		" 0.20	
Storage cost (incl. interest)		" 0.08	
Total cost			NOK 7.80
Allowance to cover fixed costs per kilo of raw material			NOK 2.45

Comments on the computation:

38.

We elected to use the least favourable computation with regard to cost of raw material. One major problem with regard

to sorting roe herring is namely: what to do with the milt herring? This has been a problem for many plants since alternatives to the "Japan contracts" have been few and often not very profitable. For plants, particularly in North Norway, where transportation, distance and costs make it difficult to compete on the fresh fish market in Denmark and West Germany, the milt herring could be considered a "problem". Frozen filets and round herring supplied to East European countries under contract are normally produced from smaller herring (Gr. II) at considerably lower raw material prices.

In principle, there are many sound ways to use milt herring and possibly also contribute positively when comparing "unsorted packed" to "sex sorted roe herring"[5]. This will, however, depend on the individual plant's market contacts. Regardless, alternative use of milt herring will be a main component in the computation as the cost of raw material is also normally a heavy cost component.

39.

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[5] We presume here that packing is either of unsorted, or packed sorted roe herring. Ideally, it might be better to look at the possibilities of having a parallel production where some of the milt herring is included in unsorted packing. This would probably not be accepted by the Japanese importers without a price reduction.

Another very important factor is the selling price of roe herring. In the computation above, the statement is based on concrete production figures for the winter of 88. (A contract for 100 tonnes, which was not filled due to lack of herring over 300 grammes).

In the market there have often been rather wild estimates of the price level obtainable for sex sorted herring. Anything from 50% to 100 % higher values have been mentioned.

Finally, it is evident that the direct wage costs in this case (manual sorting), will be doubled in relation to normal production. But since this cost component constitutes a relatively small portion of the total production costs, it is of lesser significance than the two previously mentioned.

5.4.3. Summary of profitability analyses.

On the whole, the examples above show a relatively large improvement in the allowance to cover direct costs for sex sorting of herring. Concretely, an improvement from NOK 0.68 to NOK 2.45 per kg is obtained. In practice, this means NOK 177,000 in improved allowance to cover direct costs per 100 tonnes of raw material purchased.
As previously mentioned, the total raw material costs were debited the account for roe herring and any further use only

provides allowance for any direct production costs. It is evident that sorted milt herring does not contribute further, neither positively nor negatively, to the computation for roe herring.

A final entry which must be included to complete the comparison is the capital cost of investment in equipment for sex sorting.

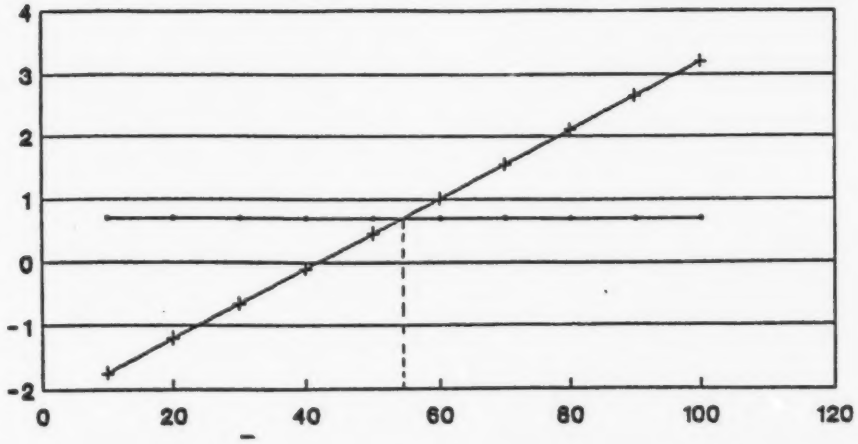
40.

In this case the investment was NOK 60,000. If written off evenly over 4 years then this adds another NOK 15,000 to the costs which must be distributed over the amount produced.

The assumptions used in our computation show that sex sorting of herring is an economically sound alternative for plants which normally have raw material and equipment for packaging consumer herring for the Japanese market.

The figure (Fig. 18) shows the effect on the allowance to cover direct costs per kilo of raw material at varying price differentials between unsorted herring and sex sorted herring. The Figure uses the same computation basis as below.

Allowance to cover fixed costs/ kilo of raw material(NOK).



Percent increased value of sorted herring

—— unsorted herring —+— sorted herring.

Figure 18: Changes in allowance to cover direct costs per unit raw material purchased at varying selling prices for sex sorted herring.

It is evident from the Figure that a selling price of NOK 8.48 will produce the same allowance to cover fixed costs for sex sorted roe herring as unsorted packed herring, that

is, NOK 0.68. In other words, the increased value of sex sorted herring, based on these assumptions, will have to be 54% higher than for unsorted packed herring in order to come out even per unit of raw material purchased. In other words, this means, that no earnings have been calculated for the milt herring. If these expenses for raw material are not necessary, then the requirement for increased price for sex sorted herring decreases correspondingly.

41.

So far, experience with commercial production of roe herring has not been very widespread. However, we know that there has been a demand for this product where price increases of up to 100 percent compared to unsorted herring have been offered. This clearly indicates that sex sorting of herring can be a highly interesting production alternative.

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Inventor: Eng. Helmer Dahl, Rolf Olsen A/S, Bergen

(Norsk patent nr. 90487; 28. september 1957: Fremgangsmåte til sortering av sild og fisk, og anordning til utførelse av fremgangsmåten.)

(2) United States Patent no 4,051,952; Oct.4. 1977.

FISH CHARACTERISTIC DETECTING AND SORTING APPARATUS

Inventors: E.G. Hauptmann; J.R. Green.

Assignee: Neptune Dynamics LTD, North Vancouver, Canada.

(3) Richardsen, R (1987): "Herring and herring roe on the Japanese market. Report of a study trip to Japan, Sept. 86."

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("Sild og silderogn i det japanske marked. Referat fra studietur til Japan, sept. -86.")

(4) Richardsen, R. (1988): "Herring and herring roe on the Japanese market."

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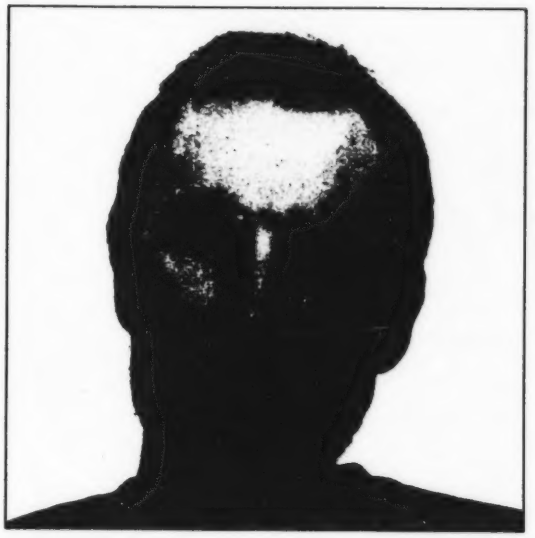
("Sild og silderogn i det japanske marked.")



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